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SPECIFICATION

1. Title of the Invention: Thin Film Magnetic Head

2. Claims

1. A thin film magnetic head comprising a magnetic circuit comprising at least a lower core, an upper core and an intermediate core connecting therebetween, a magnetic gap being formed at any position of core junctions,

said lower core, upper core and intermediate core comprising a magnetic material filled in a groove formed in each insulation layer, and

the surface of each insulation layer including the junction surface of each core being planarized.

2. The thin film magnetic head according to Claim 1, wherein the side wall of at least the intermediate core among the upper core, lower core and intermediate core is

nonparallel to the direction of thickness of the insulation layer, and is tapered toward a magnetic gap forming portion.

3. The thin film magnetic head according to Claim 1, wherein at least one layer of a dry-etching resistant layer comprising a metal oxide, metal fluoride or metal is formed on either the lower core, upper core or intermediate core.

3. Detailed Description of the Invention

[Technical Field of the Invention]

The present invention relates to a thin film magnetic head of a magnetic recording regeneration apparatus, particularly to a thin film magnetic head for high density magnetic recording.

[Description of Related Art]

A magnetic circuit was formed in the conventional thin film magnetic head by forming a magnetic layer by a thin film vacuum deposition method, by machining the magnetic layer into a given core shape by a photolithographic method or etching, and by forming a magnetic layer with interposition of a core and an insulation layer.

Figs. 8(A) and 8(B) show the conventional thin film magnetic head 10. Fig. 8(A) shows a schematic plane view, and Fig. 8(B) shows a schematic cross section along the cutting line A-A in Fig. 8(A).

In the drawing, the reference numeral 11 denotes a

substrate, the reference numeral 12 denotes a lower core formed on the substrate, and the reference numeral 13 denotes an upper core.

One end of the lower core is joined to one end of the upper core with interposition of a nonmagnetic material 14 to form a magnetic gap 16 on a sliding surface 15 against a recording medium, and the other end of the lower core is directly bonded to the other end of the upper core to form a rear junction 17.

Spiral coil patterns 19 are formed in a space where the upper core 13 faces the lower core 12 so as to surround the rear junction 17 with interposition of a nonmagnetic material 14 and an insulation layer 18. Junction patterns 20 and 21 are formed at the leading end and terminating end of the coil pattern. The coil pattern 19 is covered with an insulation layer 22.

In the conventional thin film magnetic head 10, a track width (t) is formed at the junction in the horizontal direction, where the upper core 13 and lower core 12 are joined with interposition of the nonmagnetic material 14 of the sliding surface 15 against the recording medium.

The method for manufacturing the conventional thin film magnetic head will be described below.

A magnetic layer is formed on the substrate 11 at first, and the lower core 12 is formed by a well known method such

as photolithography and etching.

Then, a nonmagnetic layer 14 is deposited on the lower core so that the end of the nonmagnetic layer serves as the magnetic gap 16, and unnecessary portions are removed by photolithography or etching. Subsequently, an insulation layer 18 is formed followed by removing the unnecessary portions by photolithography or etching. A conductive layer is formed on the insulation layer, and the coil patterns 19 are formed by photolithography or etching. An insulation layer 22 is formed on the terraced coil-forming surface on which the coil patterns are is formed, and unnecessary portions are removed by photolithography or etching as in the foregoing steps.

Then, a magnetic layer is formed by the vacuum thin film deposition method to form the lower core 12 and junction 17 in the inner circumference of the coil patterns 19. The upper core 13 is formed thereafter by removing unnecessary portions as described above.

Lead wires are connected to the junction patterns 20 and 21, and a protective layer 24 is formed when the thin film magnetic head thus formed is practically used.

[Problems to be Solved by the Invention]

However, since the insulation layer 22 is formed on the insulation layer 18 and terraced coil patterns 19 while the upper core 13 is further formed on the insulation layer 22

in the conventional thin film magnetic head 10 as described above, the terrace height increases as the layers are piled up.

For example, when the thickness of each of the both cores is usually about 5 μm and the thickness of the coil pattern is about 3 μm, the terrace height reaches 10 μm immediately before forming the upper core.

Resolution of photolithography is extremely worsened on such terraced surface with a limitation of resolution in the order of the terrace height. Accordingly, the pitch distance between the coil patterns 19 cannot be reduced due to poor resolution when the coil patterns are desired to be small for increasing the number of winding of the coil. Consequently, the lengths of the upper and lower cores 12 and 13 formed on and under the coil patterns should be increased to result in a higher magnetic resistance due to an increased length of the magnetic circuit, thereby arising a problem of poor performance as the thin film magnetic head.

[Means for solving the Problems]

The present invention for solving the problems above is to provide a thin film magnetic head comprising a magnetic circuit composed of at least a lower core, an upper core and an intermediate core connecting therebetween with a magnetic gap formed at any position of core junctions. The lower core, upper core and intermediate core comprise a magnetic

material filled in a groove formed in each insulation layer, and the surface of each insulation layer including the junction surface of each core is planarized.

[Examples]

[Example 1]

Fig. 1 shows a schematic cross section of the thin film magnetic head 30 according to the present invention.

While the thin film magnetic head 30 is described below with reference to the drawings, the same reference numerals are given to the same constituting elements as those of the conventional thin film magnetic head 10, and descriptions thereof are omitted.

As shown in Fig. 1, a planarized lower insulation layer 31a is formed on a substrate 11. A magnetic material is filled in a groove formed on the lower insulation layer 31a so as to form a planarized lower core 12 with no terraces between the lower insulation layer.

An intermediate insulation layer 31b is formed on the lower insulation layer 31a. An intermediate core 33a comprising a magnetic material is embedded at the end of the intermediate insulation layer 31b (at a sliding surface side 15 against a recording medium) with interposition of a magnetic gap 16 so as to be connected to the lower core 12. An intermediate core 33b comprising a magnetic material is embedded at the inner side with a distance apart from the

intermediate core 33 so as to directly contact the lower core 12.

A planar coil pattern 19 is embedded within the intermediate insulation layer 31b as a spiral surrounding the intermediate core 33b. One end of the coil pattern 19 is bonded to an external lead wire 35 via a conductive material embedded in a through-hole 34 drilled through an upper insulation layer 31c to enable the coil pattern to be electrically connected to an auxiliary equipment.

The upper insulation layer 31c is formed on the intermediate insulation layer 31b, and an upper core 13 is formed on the upper insulation layer 31c so that both ends of the upper core are bonded to the intermediate cores 33a and 33b, respectively, to form a magnetic circuit together with the lower core 12.

Three planarized insulation layers, or the lower insulation layer 31a, intermediate insulation layer 31b and upper insulation layer 31c, are piled in the thin film magnetic head of the present invention, and the magnetic circuit is formed by connecting the magnetic layers formed at given positions within the insulation layers 31a, 31b and 31c. Consequently, photolithographic processing is possible on each insulation layer surfaces having no terraces to enable a miniature size coil pattern and magnetic cores to be obtained with high dimensional accuracy. Therefore, a

thin film magnetic head having small magnetic resistance and high performance can be obtained.

The method for manufacturing the thin film magnetic head 30 according to the present invention will be then described below.

Figs. 2(A) to 2(K) are schematic cross sections showing the manufacturing process of the thin film magnetic head 30 according to the present invention.

The manufacturing method is described below with reference to the drawings.

Step 1 The insulation layer 31a comprising, for example, SiO_2, TiO_2, Al_2O_3 or WO_3 is formed on the substrate 11 with a thickness of 1 to 10 μm by a thin film vacuum deposition method such as sputtering, vacuum deposition and CVD. Then, grooves 12a for forming the cores 12 to be described hereinafter are formed by photolithography or etching (Fig. 2(A)).

Step 2 A magnetic material such as a soft magnetic material mainly comprising Fe, Co and Ni is formed by the vacuum thin film deposition method or plating with a thickness larger than the depth of the groove 12a, and the magnetic layer deposited in excess is removed by grinding to form a lower core 12 having a planarized surface with no terrace between the insulation layer 31a (Fig. 2(B)).

Step 3 An intermediate insulation layer 31b of, for example,

SiO_2, TiO_2, Al_2O_3 or WO_3 is formed on the planarized insulation layer 31a including the lower core 12 with a thickness of 1 to 5 μm by the thin film vacuum deposition method (Fig. 2(C)).

Step 4 A coiled groove is formed in the intermediate insulation layer 31b by the same method as forming the core 12 so that the groove does not reach the lower core 12, and a conductive material such as Cu, Al, Au or Ag is deposited thereafter in the groove by the vacuum thin film deposition method. The conductive material deposited at the portions other than the groove is removed by grinding, and a coil pattern 19 is formed by planarizing the surface (Fig. 2(D)).

Step 5 Another insulation layer 32 is formed with a thickness of 0.1 to 1 μm on the intermediate insulation layer 31b on which the coil pattern 19 is formed (Fig. 2(E)).

Step 6 A groove 33a' having side walls parallel to the direction of thickness of the insulation layer is formed by cutting from the insulation layer 32 to the intermediate insulation layer 31b by the photolithographic method or etching method so as to leave a thickness corresponding to a magnetic gap 16 to be described hereinafter behind (Fig. 2(F)).

Step 7 A groove 33b' having side walls parallel to the direction of thickness of the insulation layer is also formed by the same method as forming the groove 33a'.

However, the groove 33b' is formed so that a part of the lower core 12 is exposed (Fig. 2(G)).

Step 8 The soft magnetic material is deposited in the groves 33a' and 33b' by the thin film vacuum deposition method as used in forming the lower core 12. The excess magnetic material on the surface is removed to form intermediate cores 33a and 33b having planarized surfaces (Fig. 2(H)).

Step 9 An upper insulation layer 31c comprising, for example, SiO_2, TiO_2, Al_2O_3 or WO_3 with a thickness of 1 to 10 μm is deposited on the intermediate insulation layer 31b comprising the intermediate cores 33a and 33b (Fig. 2(I)).

Step 10 An upper core 13 is formed by the same method as forming the lower core 12 (Fig. 2(J)).

Step 11 A through-hole 34 connected to one end of the coil pattern 19 is formed in the upper insulation layer 31C. The conductive material is filled in the through-hole, and a lead wire 35 is further formed on the insulation layer 31C by the thin film vacuum deposition method or plating to electrically connect the coil pattern to the conductive material filled in the through-hole.

Finally, the substrate is cut along the cutting line B-B so that the magnetic gap 16 comes to the end to obtain the thin film magnetic head shown in Fig. 1 (Fig. 2(K)).

[Example 2]

Fig. 3 is a schematic cross section showing another embodiment of the thin film magnetic head 40 according to the present invention.

The thin film magnetic head 40 of this example differs from the thin film magnetic head 30 above in that the coil pattern 41 formed within the intermediate core 33 is three-dimensionally connected to the coil pattern 43 formed on the insulation layer 42 deposited on the upper core 13 via the conductive material 45 filled in a plurality of through-holes 44 in this example, although the coil pattern 19 is embedded only in the intermediate insulation layer 31b and is formed into a planar coil. Accordingly, the size of the coil can be reduced as compared with the thin film magnetic head 30 in the foregoing examples. Therefore, performance of the thin film magnetic head is improved while the thin film magnetic head may have a high track density when a multi-track magnetic head is manufactured.

[Example 3]

Fig. 4 is a schematic cross section showing a different embodiment of the thin film magnetic head 50 according to the present invention.

The thin film magnetic head shown in Fig. 4 is different from the magnetic head 30 shown in Example 1 in that the side walls 51a' and 51b' of the intermediate cores 51a and 51b are not formed in parallel to the direction of

thickness of the insulation layer, instead grooves 52 and 53 having widths tapered in the vicinity of the magnetic gap 16 forming portions are used.

The magnetic field is concentrated at the tip of the magnetic gap 16 in the thin film magnetic head 50 so configured as described above to enable more efficient recording to be achieved.

While a service life dimension is determined by the depth (d) of the magnetic gap 16, the magnetic circuit is not blocked by abrasion of the intermediate core 51 before the depth reaches the service life dimension when the width of the intermediate core 51 is narrowed in the vicinity of the magnetic gap 16 forming portion as in this example. Consequently, efficient recording and reproduction are possible until the service dimension is reduced to zero.

The essence of the method for manufacturing the thin film magnetic head 50 of this example will be described below.

The manufacturing method in this example differs from the manufacturing method in Example 1 in that the side walls are not formed to be parallel to the direction of thickness of the insulation layer in steps 6 and 7. Instead, a groove 52 having an width tapered in the vicinity of the magnetic gap 16 forming portion, and a groove 53 having an width tapered at the portion in contact with the lower core 12 are

formed by, for example, an RIE (reactive ion etching) method. In other words, when a mask such as a photoresist is formed on the insulation layer 31b that is etched from above the surface of the mask, the grooves 52 and 53, which have no side walls parallel to the direction of thickness of the insulation layer and in which the bottom area of the groove is smaller than the opening area of the groove, are formed by using a gas having a higher etching rate of the insulation layer 31b than the etching rate of the mask (or a gas having a smaller selectivity ratio).

While the magnetic gap 16 is formed between the lower core 12 and intermediate core 51 in Example 3, it is needless to say that the same effect is obtained by forming the magnetic gap 16 between the upper core 13 and intermediate core 51.

[Example 4]

Fig. 5 is a schematic cross section showing the embodiment of the thin film magnetic head 60 according to the present invention.

The thin film magnetic head 60 in this example differs from that in Example 3 in that a dry-etching resistant layer 61 is formed at least on the lower core 12 within the magnetic circuit.

The etching resistant layer 61 is formed of an insulation material comprising a metal oxide or metal

fluoride having a low fry etching rate such as $CaTiO_3$, $BaTiO_3$, α-Fe_2O_3, ZrO_2, $MgAl_2O_4$, MgF_2 and CaF_2, rather than the intermediate insulation layer 31b having a high etching rate made of, for example, TiO_2, SiO_2, Al_2O_3 and WO_3.

The groove does not reach the lower core 12, and insulation between the coil and lower core is not broken by forming the dry-etching resistant layer 61 on the lower core 12, when the groove for the coil pattern 19 is formed by dry-etching. Since the coil pattern 19 is formed with a larger thickness of the coil, a thin film magnetic head having a low resistance and high S/N ratio can be provided.

[Example 5]

Fig. 6 is a main part of a schematic cross section showing a further different embodiment of the thin film magnetic head 70 according to the present invention.

While the dry-etching resistant layer 61 is formed on the lower core 12 in Example 4, a dry-etching resistant layer 62 is formed under the upper core 13 in Example 5, and an insulation layer 63 similar to the intermediate insulation layer 31b is provided thereon to form a coil pattern 19' as in Example 1.

Since the dry-etching resistant layer 62 is formed as described above, the coil pattern 19' is not etched by forming the upper core 13. Consequently, the upper core 13 does not contact the coil pattern 19'.

In the manufacturing method of this example, an insulation material comprising the metal oxide or metal fluoride such as $CaTiO_3$, $BaTiO_3$, α-Fe_2O_3, ZrO_2, $MgAl_2O_4$, MgF_2 and CaF_2 is deposited as the dry-etching resistant layer 62 on the flat surface of the intermediate insulation layer 31b on which the coil pattern 19 is formed in step 4 of Example 1, and the portion where an intermediate core is to be formed is removed by ion-milling. As a result, the grooves for the intermediate core and upper core can be formed at one stroke from above the upper insulation layer, instead of independently forming the grooves for the intermediate core and upper core as in Example 1, in etching the upper insulation layer, because the dry-etching resistant layer has been formed on the surface where the coil pattern was formed. Consequently, the manufacturing process may be simplified.

The same effect may be expected by forming the dry-etching resistant layer on the upper core.

[Example 6]

While the insulation material comprising the metal oxide or metal fluoride such as $CaTiO_3$, $BaTiO_3$, α-Fe_2O_3, ZrO_2, $MgAl_2O_4$, MgF_2 and CaF_2 was formed for the dry-etching resistant layers 61 and 62 in Examples 4 and 5, a metal layer having a low dry-etching rate such as Ni, Fe, Co and Al may be formed on the insulation layer.

Fig. 7 is a main part of a cross section showing a further different embodiment of the thin film magnetic head 80 according to the present invention.

In the drawing, the reference numeral 71 denotes an insulation layer having a high etching rate such as TiO_2, SiO_2, Al_2O_3 and WO_3, and is formed on the coil pattern 19 with a thickness of 0.1 to 1 μm. The reference numeral 72 denotes a dry-etching resistant layer comprising a metal having a low etching rate such as Ni, Fe, Co and Al, which is formed on the insulation layer 71.

While this example differs from Example 4 in the material of the insulation layer, the metal layer 72 has a lower etching rate when the insulation material comprising the metal oxide or metal fluoride such as $CaTiO_3$, $BaTiO_3$, α-Fe_2O_3, ZrO_2, $MgAl_2O_4$, MgF_2 and CaF_2 is compared with the metal having a low etching rate such as Ni, Fe, Co and Al as the dry-etching resistant layer. When the insulation material is compared with the metal in terms of selectivity ratio of the insulation layer 71 (or intermediate insulation layer 31b) to the dry-etching resistant layer 61 (or 62 or 72), for example, the insulation material ($CaTiO_3$, $BaTiO_3$, α-Fe_2O_3, ZrO_2, $MgAl_2O_4$, MgF_2 and CaF_2) has a selectivity ratio of 5 to 10 while the selectivity ratios of Ni, Co, Fe and Al are 25, 20 to 30, 10 to 20 and 10, respectively. These results show that metals have several times as large as the selectivity

ratio than the insulation materials.

Since the magnitude of the etching rate of the dry-etching resistant layer is inversely proportional to the selectivity ratio, the accuracy of etching is improved by using the dry-etching layer 72 having a large selectivity ratio to enable a high performance thin film magnetic head to be provided.

On the other hand, since etching with a sufficiently high accuracy is possible even by wet-etching by using the dry-etching resistant layer 72 comprising the metal, the step for removing the dry-etching resistant layer 72 at the position where the intermediate core is to be formed is simplified after depositing the dry-etching resistant layer 72. Accordingly, the manufacturing process is simplified and accuracy of processing is improved.

While the vicinity of the magnetic circuit has been described as the main part in Examples 4 to 6, it is needless to say that the effect is common between the thin film magnetic head having the coil pattern formed only on the intermediate insulation layer 31b and the thin film magnetic head having the multi-layer coil patterns.

[Advantages]

The present invention provides a thin film magnetic head having a magnetic circuit comprising at least a lower core, upper core and an intermediate core connecting both

cores with magnetic gaps formed at any junctions of the cores. The upper core, lower core and intermediate core are formed of a magnetic material filled in grooves formed in each insulation layer, and the surface of each layer including the junction surface between the cores is planarized. Accordingly, no terraces are formed while the magnetic cores and core patterns are formed with high accuracy to enable a thin film magnetic head having excellent magnetic characteristics to be provided.

4. Brief Description of the Drawings

Fig. 1 is a schematic cross section showing the thin film magnetic head according to the present invention.

Figs. 2(A) to 2(K) are schematic cross sections showing the steps for manufacturing the thin film magnetic head according to the present invention.

Fig. 3 is a schematic perspective view showing another embodiment of the thin film magnetic head according to the present invention.

Fig. 4 is a schematic perspective view showing a different embodiment of the thin film magnetic head according to the present invention.

Figs. 5, 6 and 7 show main parts of the schematic cross sections showing different embodiments of the thin film magnetic head according to the present invention.

Figs. 8(A) and 8(B) show the conventional thin film magnetic head.

30, 40, 50, 60, 70, 80: thin film magnetic head according to the present invention

11: substrate

12: lower core

13: upper core

16: magnetic gap

31a: lower insulation layer

31b: intermediate insulation layer

31c: upper insulation layer

19, 19', 41, 43: coil pattern

33a, 33b, 51a, 51b: intermediate core

51': side wall

d: depth

52, 53: groove

61, 62, 72: etching resistant layer

63, 71: insulation layer

AMENDMENT

November 28, 1989

Commissioner of the Patent Office

1. Indication of the Case

Patent Application No. 193469, 1989

2. Title of the Invention

Thin Film Magnetic Head

3. Applicant of Amendment

Relation to the Case: Applicant

Address: 3-12 Moriya-cho, Kanagawa-ku, Yokohama

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Representative: Kunio Kakigi

4. Date of Instruction of Amendment

Voluntary Amendment

5. Object of Amendment

"Detailed Description of the Invention", "Brief Description of the Drawings" and Drawings.

6. Contents of Amendment

(1) The phrase "through-holes 44" in Japanese specification page 12 line 4 and in English translation page 11 line 9 to 10 is amended as "through-holes (not shown)".

(2) The phrase "and an insulation layer 63 similar to the intermediate insulation layer 31b is provided thereon" in

Japanese specification page 16 lines 3 to 4 and English translation page 14 lines 18 to 20 is deleted.

(3) The figure "63" in Japanese specification page 21 line 11 and English translation page 19 line 18 is deleted.

(4) Fig. 6 in the drawing is amended as described in the separate paper attached.